

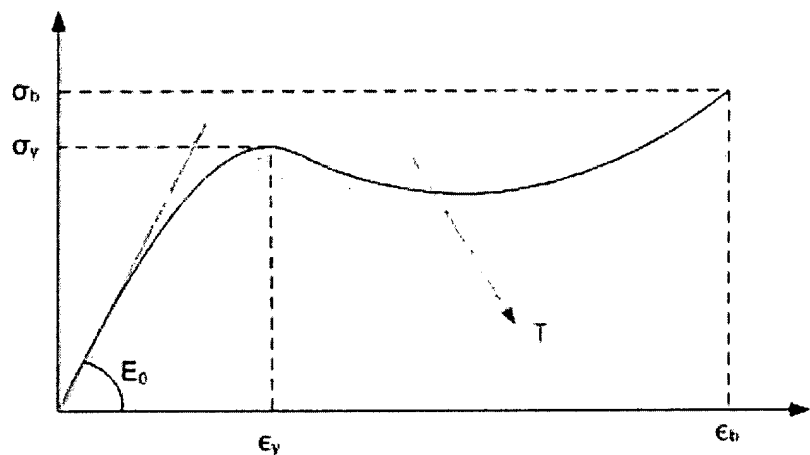
# Thermoplastic

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A **thermoplastic** is a material that is plastic or deformable, melts to a liquid when heated and freezes to a brittle, glassy state when cooled sufficiently. Most thermoplastics are high molecular weight polymers whose chains associate through weak van der Waals forces (polyethylene); stronger dipole-dipole interactions and hydrogen bonding (nylon); or even stacking of aromatic rings (polystyrene). Thermoplastic polymers differ from thermosetting polymers (Bakelite; vulcanized rubber) which once formed and cured, can never be remelted and remolded. Many thermoplastic materials are addition polymers; e.g., vinyl chain-growth polymers such as polyethylene and polypropylene.

## Temperature dependence

Thermoplastics are elastic and flexible above a glass transition temperature  $T_g$ , specific for each one — the midpoint of a temperature range in contrast to the sharp freezing point of a pure crystalline substance like water. Below a second, higher melting temperature,  $T_m$ , also the midpoint of a range, most thermoplastics have crystalline regions alternating with amorphous regions in which the chains approximate random coils. The amorphous regions contribute elasticity and the crystalline regions contribute strength and rigidity, as is also the case for non-thermoplastic fibrous proteins such as silk. (Elasticity does not mean they are particularly stretchy; e.g., nylon rope and fishing line.) Above  $T_m$  all crystalline structure disappears and the chains become randomly interdispersed. As the temperature increases above  $T_m$ , viscosity gradually decreases without any distinct phase change.



Thermoplastics can go through melting/freezing cycles repeatedly and the fact that they can be reshaped upon reheating gives them their name. Animal horn, made of the protein  $\alpha$ -keratin, softens on heating, is somewhat reshapable, and may be regarded as a natural, quasi-thermoplastic material.

Some thermoplastics normally do not crystallize: they are termed "amorphous" plastics and are useful at temperatures below the  $T_g$ . They are frequently used in applications where clarity is important. Some typical examples of amorphous thermoplastics are PMMA, PS and PC. Generally, amorphous thermoplastics are less chemically resistant and can be subject to stress cracking.

Most other thermoplastics will crystallize to a certain extent and are called "semi-crystalline" for this reason. Typical semi-crystalline thermoplastics are PE, PP, PBT and PET. The speed and extent to which crystallization can occur depends in part on the flexibility of the polymer chain. Semi-crystalline thermoplastics are more resistant to solvents and other chemicals. If the crystallites are larger than the wavelength of light, the thermoplastic is hazy or opaque.

Semi-crystalline thermoplastics become less brittle above  $T_g$ . If a plastic with otherwise desirable properties has

too high a  $T_g$ , it can often be lowered by adding a low-molecular-weight plasticizer to the melt before forming (Plastics extrusion; molding) and cooling. A similar result can sometimes be achieved by adding non-reactive side chains to the monomers before polymerization. Both methods make the polymer chains stand off a bit from one another. Before the introduction of plasticizers, plastic automobile parts often cracked in cold winter weather. Another method of lowering  $T_g$  (or raising  $T_m$ ) is to incorporate the original plastic into a copolymer, as with graft copolymers of polystyrene, or into a composite material. Lowering  $T_g$  is not the only way to reduce brittleness. Drawing (and similar processes that stretch or orient the molecules) or increasing the length of the polymer chains also decrease brittleness.

Although modestly vulcanized natural and synthetic rubbers are stretchy, they are elastomeric thermosets, not thermoplastics. Each has its own  $T_g$ , and will crack and shatter when cold enough so that the crosslinked polymer chains can no longer move relative to one another. But they have no  $T_m$  and will decompose at high temperatures rather than melt. Recently, thermoplastic elastomers have become available.

## List of thermoplastics

- Acrylonitrile butadiene styrene (ABS)
- Acrylic
- Celluloid
- Cellulose acetate
- Ethylene-Vinyl Acetate (EVA)
- Ethylene vinyl alcohol (EVAL)
- Fluoroplastics (PTFEs, including FEP, PFA, CTFE, ECTFE, ETFE)
- Ionomers
- Kydex, a trademarked acrylic/PVC alloy
- Liquid Crystal Polymer (LCP)
- Polyacetal (POM or Acetal)
- Polyacrylates (Acrylic)
- Polyacrylonitrile (PAN or Acrylonitrile)
- Polyamide (PA or Nylon)
- Polyamide-imide (PAI)
- Polyaryletherketone (PAEK or Ketone)
- Polybutadiene (PBD)
- Polybutylene (PB)
- Polybutylene terephthalate (PBT)
- Polyethylene terephthalate (PET)
- Polycyclohexylene dimethylene terephthalate (PCT)
- Polycarbonate (PC)
- Polyhydroxyalkanoates (PHAs)
- Polyketone (PK)
- Polyester
- Polyethylene (PE)
- Polyetheretherketone (PEEK)
- Polyetherimide (PEI)
- Polyethersulfone (PES)- see Polysulfone
- Polyethylenechlorinates (PEC)
- Polyimide (PI)
- Polylactic acid (PLA)
- Polymethylpentene (PMP)
- Polyphenylene oxide (PPO)
- Polyphenylene sulfide (PPS)
- Polyphthalamide (PPA)
- Polypropylene (PP)

- Polystyrene (PS)
- Polysulfone (PSU)
- Polyvinyl chloride (PVC)
- Spectralon

Polymerisation can only take place at double double carbon bonds

## See also

- Thermosetting plastic

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